Inhalation Therapy

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AMERICAN ASSOCIATION OF INHALATION THERAPISTS

"Inhalation Therapy"

"Inhalation Therapy" is the official publication of the American Association of Inhalation Therapists, an organization of therapy technicians working in hospitals, for firms providing emergency therapy service and for municipal organizations. The Association is sponsored jointly by the American College of Chest Physicians and the American Society of Anesthesiologists. Contents include news and information pertinent to the profession including medical research, operative techniques, and practical administration.

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Editorial

The Professional Attitude

RECENTLY I heard the medical director of a great corporation address a group of doctors. His subject, research. He spoke at some length, but what he had to say was, in brief, simply this:

"Research, gentlemen, is a state of mind."

In other words, you can have all the million dollar laboratories, plus millions of dollars worth of equipment, plus all the high-powered talent in the world—but without a certain state of mind, or, if you will, attitude, you cannot have honest-to-God Research.

Applying these remarks to our own situation here in the American Association of Inhalation Therapists, I would like to suggest that becoming a truly professional inhalation therapist is also a state of mind.

To achieve that state of mind, however, is not easy. It is not possible to all people, and there are some who will never have it.

Mere wishing won't do it; neither will over-powering self-esteem. In short, no one can become a professional simply by claiming to be one. It takes more than wishful thinking.

Well then, what is this process? How, for example, does an occupation become a profession? And how does an individual become a member of that profession? What are some of the first steps? How does this thing we call professionalism develop? And is a consideration of these questions pertinent to this group? Meaningful to this Association?

I believe—and I think you do too, that they are of the utmost importance.

Consider, first, what it is that makes the difference between a profession and an occupation.

Obviously, what distinguishes these two is that an occupation is simply a way of earning a living. A **profession,** on the other hand, is a way of earning a living **that is guided by a code of ethics.**

And the difference between a mere job-holder and a true professional man—be he doctor, engineer, lawyer, architect—or, indeed, a trained inhalation therapist—is his willingness to be guided by such a code of ethics.

But there are other considerations. Actually, the concept of a profession grew out of the natural social and economic developments which are our history. Because of the division of labor principle inherent in

the industrial revolution, life became increasingly complex. In other words, by emphasizing certain skills and using a body of knowledge which had been accumulated in a single area, men became experts at one single job. Other men became dependent upon these specialists for the gratification of one single need. If shoes were wanted, you went to a cobbler; for a suit of clothes, to a tailor; for medical care, at first, to a barber; later on to a physician.

As society developed, and as we became more sophisticated, the professions became more learned, more dignified, more trustworthy.

Out of this lengthy process evolved a few fundamental principles which characterize any method of earning a living which we call a profession.

Most important, it seems to me, is that any profession must depend on a body of knowledge and upon the accumulation of certain technical skills.

Second, I think, is the idea of service to one's fellow men. I put this second because an ignorant man can have the best of intentions, but if he does not possess the knowledge and skill, Lord help the patient.

And, finally, to be a member in good standing of any profession, all persons should be subject to an accepted discipline. I might add that the professional status which such people attain, as well as the respect which they receive from their associates in medicine and related fields, will be in direct proportion to their mastery of this discipline.

So much—very sketchily—for a consideration of what we mean by a profession, and how the concept developed.

Going from the general to the particular, to the individual himself; what is a professional? And what are some of the things he must do to measure up to what is expected of him? To be truly a professional man, 10 things are basic.

Certainly, foremost is a belief in God, for how can any one be a conscientious professional man without faith.

Second, I think, and strongly motivated by this faith, is a sincere desire to relieve human suffering. If this sounds somewhat sentimental for some of you with scientific training, let's rephrase it. Let's say that the true professional has a genuine desire to work for socially desirable ends.

Very much in line with the first two requirements is that a professional has a realization of his own limitations. This means that he possesses humility rather than arrogance. It means that he is not ashamed to admit when he does not know something; it means that he is not a know-it-all. When in doubt, or when he needs help—he seeks the counsel of his fellow members.

The fourth requirement is this: that he possess an insatiable desire to keep learning. He realizes that education never stops, and so he is constantly on the alert for new discoveries, new techniques. Inhalation therapy is, after all, a new frontier in medicine. Exciting and beneficial things are continually being discovered and reported. The professional does his level best to keep himself aware of these latest developments.

As number five in this list I put a more personal thing, an unceasing effort to improve himself not just professionally, as a technician and in greater knowledge, but as a human being. He tries to have good human relations. This means he wants to get along with people, all the people with whom he must deal in doing his job: patient, nurse, doctor, administrator, commercial men and other medical specialists.

To this end he is cooperative both at his work and at home, in the community and in his professional organization. People who know him respect him, and in so doing they respect the profession of inhalation therapy. He serves as a symbol of this association, and he realizes that it is no little responsibility.

The sixth mark of a true professional is an unselfish desire to share his knowledge and know-how with others. He is always willing to help beginners, without being sarcastic or conceited. He has an honest desire to help his local chapter, is willing to assume his share of the work this involves. He is just as eager to help the national organization, by serving on committees, helping to organize meetings, plan programs, and write articles for the official publications.

In seventh place, I put a sincere desire to be above petty bickering, jealousy, narrow-mindedness, or indulgence in malicious gossip or mischief. Nothing can ruin an organization faster than a group of people who refuse to make allowance for human weakness, who won't give credit where it is due, and who play politics. Your true professional does not lower himself by indulging in these things because he realizes that they are most unprofessional.

As the eighth requirement, I put an awareness of the meaning of science, its place in the scheme of things, its limitations. Certainly the competent inhalation therapist should have a fundamental grasp of the scientific method and what it means. He should also understand something of the enormous contribution of the scientific method to the progress and well-being of mankind, and, particularly, its conquests over ignorance and superstition.

In ninth place I place a sincere desire to do everything in his power to advance the cause of inhalation therapy. Thus he believes in the worth and dignity of his fellow members. He praises them for their good performance, and is genuinely pleased when an associate wins an advancement or receives honors.

The tenth requirement is somewhat related to the third, that is, an awareness of his limitations. But I am putting it by itself because of its vital importance in realizing that we are a para-medical group, not a medical group. The truly professional inhalation therapist never assumes the part of a doctor. That is not his job. It never has been. It never will be. To realize this and to abide by it is the distinguishing mark of the professional.

*Albert Carriere**

**This editorial is adapted from a speech given by Mr. Carriere at the annual meeting and lecture series of the American Association of Inhalation Therapists in Cleveland during November, 1957.*

Inhalation Therapists

asked to Aid Federal Civil Defense Administration

INHALATION THERAPISTS, from hospitals, medical oxygen service companies and municipal service organizations have been asked to pool their knowledge of inhalation therapy techniques and thus assist the Federal Civil Defense Administration to program the use of trained technicians and all available equipment in the event of emergencies. This request was voiced by Dr. Paul Parrino, Director, Medical Care Division, Civil Defense Administration, speaking at the 1957 Annual Meeting and Lecture Series of the American Association of Inhalation Therapists, held November 4-8 at the Hollenden Hotel in Cleveland, Ohio.

Dr. Parrino outlined for the Inhalation Therapists the current scope of the Civil Defense Administration's plans to meet emergencies brought about either by nature or acts of war. He pointed out, however, that the Civil Defense Administration has not developed a program which will help civil defense organizations to develop a coördinated use of the resuscitation and other emergency equipment, nor the technicians available through hospitals, medical oxygen service companies and the fire or police emergency rescue units.

Emergency Equipment

At the Annual Meeting, additional emphasis was placed on emergency equipment and utilization of trained personnel for emergency work by William E. Smith, Chief Engineer of the O. E. M. Corporation and by Gareth Gish of Puritan Compressed Gas Corporation. These two men discussed development of Inhalation Therapy equipment: Mr. Smith emphasizing the necessity of simplicity of design of emergency equipment; Mr. Gish discussing the needs for standardization of emergency equipment. Both of these concepts, if followed, would tend to reduce confusion in application of emergency treatment. Through the courtesy of Dr. R. A. Hingson, Professor of Anesthesia at the Western Reserve University School of Medicine in Cleveland, Ohio, the group was

Dr. Albert H. Andrews of Chicago, left, and Dr. Paul Parrino of the Federal Civil Defense Agency talk over some of the crucial points of the contribution inhalation therapists can make in time of emergency.

Don Gilbert, left, Chairman of the Board of Directors of the American Association of Inhalation Therapists, admires hand carved plaque of the insignia of the Association. The plaque was carved and presented to the association as a gift by Kurt F. Litzkuhn, right, a member of the American Association of Inhalation Therapists and an inhalation therapist at Michael Reese Hospital in Chicago. Mr. Gilbert is chief Inhalation Therapist at University Hospital, Ann Arbor, Michigan.

shown films dealing with the emergency resuscitation which emphasized that prompt and efficient utilization of inhalation therapy is often the difference between life and death.

In addition to standards for equipment and emergency care, standards of education and training were also emphasized at the meeting. Mr. James Peo, Supervisor of Inhalation Therapy at the Delaware Hospital in Wilmington, Delaware, urged that consideration be given in the American Hospital Association's accreditation program for the use of trained Inhalation Therapists in hospitals. Dr. John Hinman, of the American Medical Association's Council on Education and Hospitals, gave a report of the progress that this group has made on the study of the standards of education and training of inhalation therapists. He stated that at a council meeting last September, careful study was given to the "Essentials of an Accepted School for Inhalation Therapists" developed by a joint committee of the New York State Society of Anesthesiologists and the New York State Medical Society. The council is expected to meet again this month (December) for further study of the problem and Dr. Hinman implied that a set of standards could possibly be developed by the close of that meeting.

Training

Dr. R. I. Shapiro of Detroit, in commenting on qualifications and standards for Inhalation Therapists, pointed out that patients expect to get the same inhalation therapy in one hospital as in another and that this indicated clearly that all hospitals should provide this service by giving therapists good training in pre-medical and medical sciences. For example, he said, therapists

Chatting after one of the sessions at the meeting of the American Inhalation Therapists Association are, left to right: Dr. J. M. Brown, Director, Department of Anesthesiology, Medical College of South Carolina, Charleston, South Carolina; Vincent Kracum, Inhalation Therapy Consultant, of Ohio Chemical and Surgical Co., New York; and Dr. Vincent Collins, President of the New York State Society of Anesthesiologists. Dr. Collins is affiliated with St. Vincent's Hospital in New York City.

and nurses should both be taught to do endotracheal suctioning. Through knowledge of their equipment and techniques, he pointed out, a well-qualified therapist should be able to evaluate the treatment in progress and assist in determining what is wrong, if a patient does not respond to therapy in the expected manner.

Dr. David Gillespie of Cleveland City Hospital, reported to the Inhalation Therapists on the current development and techniques of Intermittant Positive Pressure Breathing. Dr. Gillespie pointed out that since this technique is relatively new, careful evaluation of the patient's symptoms is essential before prescribing Intermittant Positive Pressure. It is not a good idea, he said, just to try it on everybody who is dyspeic or may possibly have emphysema.

Aerosol Therapy was discussed by Dr. Joseph Miller of Mobile, Alabama. Dr. J. M. Brown, Director of Anesthesiology at the Medical College of South Carolina in discussing polio treatments, emphasized the importance of tracheotomies. Continuous Aerosol Therapy is needed to keep the trachea moist, he said. He also stressed that polio patients frequently do not need oxygen therapy and in these cases the Aerosol should be given with compressed air.

Indications of the use of gases such as Helium-Oxygen and Carbon-Dioxide Oxygen combination were discussed by Dr. B. B. Sankey of St. Luke's Hospital in Cleveland, Ohio.

The week-long lecture series was also high-lighted by three panel discussions. Dr. Albert Andrews of St. Luke's Hospital in Chicago, led a discussion on Tent Therapy. Participants were Max Glasser of Miami, Florida, Joseph Klocek of New York, Edward Leveille of Chicago, Illinois, Leah Tharaldson of Minneapolis, Minnesota. Dr. Meyer Saklad of Providence, Rhode Island, moderated a panel discussion concerned with the organizing and maintaining of an Inhalation Therapy Department. Three types of departments were discussed: in a hospital, in a municipal emergency organization and in a rental service company. Participants were Russell C. Nye of Minneapolis, Minnesota; Col. Joseph McCarthy of Chicago, Illinois; and J. H. Newell of Hammond and Gary, Indiana.

Dr. Edwin R. Levine, conducted a panel on pressure breathing. Participants were: Mr. Lawrence Fruik of Chicago, Illinois; Mr. James

Sharkey of Montreal, Quebec, Canada; and Mr. James Whitacre of Rochester, New York.

At other sessions at the Lecture Series, Dr. Max Sadove, Head of the Division of Anesthesiology at the University of Illinois, Chicago, Illinois, described the work being done in his laboratories in studying various methods of artificial respiration involving the evaluation of pressure and flow characteristics of many of the currentlv available resuscitator or controller-assistor apparatuses. The essentials of respiratory physiology were outlined by Dr. H. F. Helmholz Jr., of the Mayo Clinic in Rochester, Minnesota.

Dr. Paul Searles of Presbyterian-St. Luke's Hospital of Chicago, Illinois, reported that in his hospital a daily check is made on all floors of the methodology of using masks, tents and catheters. Records are kept of the results of this check and turned over to the teaching staff of the nursing school. Dr. Searles indicated that a considerable improvement in patient services as far as inhalation therapy is concerned, resulted from the introduction of this system. Dr. Vincent Collins, president of the New York State Society of Anesthesiologists, emphasized the necessity of inhalation therapy for the postoperative and convalescent cardiac surgery patient.

A proposed Code of Ethics was introduced to the membership at the meeting by Sister M. Yvonne of St. Francis Hospital, LaCrosse, Wisconsin. This Code of Ethics was adopted and will be printed in the next issue of Inhalation Therapy.

Five new Chapter Charters were presented at the Inhalation Therapists meeting. These went to the Montreal Chapter, the Bay County Chapter with headquarters at Bay City, Michigan; Upper Mid-west Chapter with headquarters at Minneapolis, Minnesota; the Ohio Chapter with headquarters in Cleveland, Ohio; and the Western New York Chapter which includes the cities of Buffalo and Rochester and surrounding counties. These five Chapters bring the total of chartered A.A.I.T. Chapters to eleven.

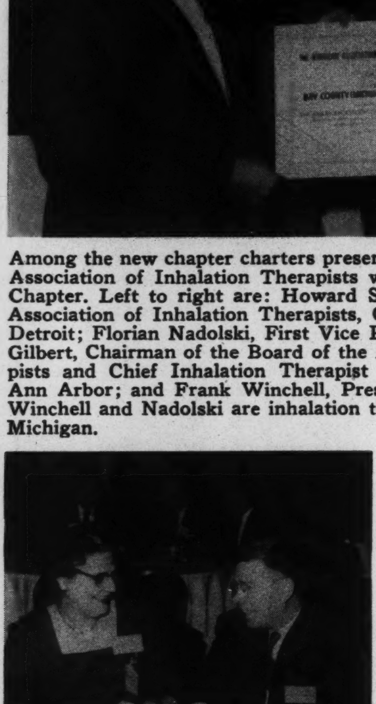
Officers Elected

James E. Peo, Supervisor of Inhalation Therapy at the Delaware Hospital in Wilmington, Delaware, was elected President of the Association for the coming year. He will serve until the Association's next annual meeting in 1958.

Elected to serve with Mr. Peo were: Don Gilbert, Chief Inhalation Therapist, University of Michigan Hospital, Ann Arbor, Michigan, First Vice-President; Lawrence Fruik, Chief Inhalation Therapist, Edgewater Hospital, Chicago, Illinois, Second Vice-President; and

Mr. J. H. Newell left, Hammond, Ind., who participated in the panel discussion on department organization and Dr. Joseph B. Miller of Mobile, Ala.

Among the new chapter charters presented at the annual meeting of the American Association of Inhalation Therapists was this one to the Bay County Michigan Chapter. Left to right are: Howard Skidmore, Past President of the American Association of Inhalation Therapists, Chief Inhalation Therapist, Sinai Hospital, Detroit; Florian Nadolski, First Vice President of the Bay County Chapter; Don Gilbert, Chairman of the Board of the American Association of Inhalation Therapists and Chief Inhalation Therapist at the University of Michigan Hospital, Ann Arbor; and Frank Winchell, President of the Bay County group. Messers. Winchell and Nadolski are inhalation therapists at General Hospital in Bay City, Michigan.



Leah Tharaldson, newly elected Director of the American Association of Inhalation Therapists discusses the problems of inhalation therapists from the Central Northwest states with James Peo, newly elected President of the Association. Mrs. Tharaldson is Director of the Anesthesia and Inhalation Therapy Departments at Northwestern Hospital in Minneapolis, and Mr. Peo is Supervisor of Inhalation Therapy at the Delaware Hospital, Wilmington, Delaware.

Agnes Forrest, also of Edgewater, Secretary-Treasurer.

Howard Skidmore, Chief Inhalation Therapist, Sinai Hospital, Detroit, Michigan, who has served as President since November 1956 becomes a Director, ex officio, to serve until November 1958.

Among the newly elected Directors of the Association is Leah Tharaldson, CRNA, Director, Anesthesia and Inhalation Therapy Departments, Northwestern Hospital, Minneapolis, Minnesota, who will serve until November, 1959. Other new Directors, all elected to serve until November, 1960 are: Constance Cypert, Supervisor of Inhalation Therapy, Inter-Community Hospital, Covina, California; Bruce

(Please turn to page 26)

Respiration Physiology

Transport of Respiratory Gases By the Blood

This is the last of a series of four articles on basic respiratory physiology. The preceding three have covered apparatus & mechanics of respiration, lung volumes & composition of respired gases, and the nervous & chemical control of the respiratory process. The concluding paragraphs of the present paper are a recapitulation of the salient points of the series.

THE oxygen requirements of living cells of the body are not met merely by breathing oxygen-containing air into the lungs; neither can carbon dioxide produced by these cells be breathed out of the lungs without first getting from the cells to the lungs.

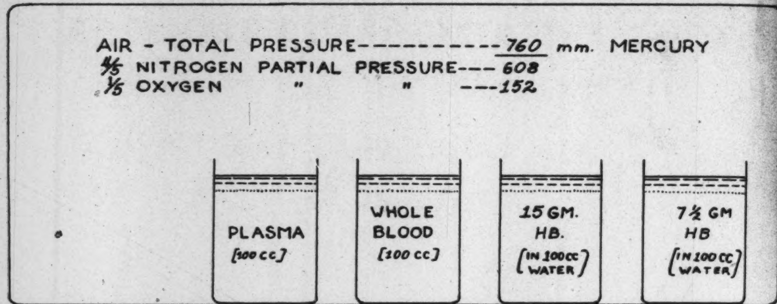
The transport system responsible for getting these gases to their respective destinations is, of course, the bloodstream. What we wish to understand is how the fluid blood manages to carry these gaseous substances. Several physical and chemical processes are concerned which we will try to analyze separately, but it must be kept in mind that most of them are going on simultaneously.

The process of getting gases into or out of the blood as it passes through the lungs has already been described in the discussion of diffusion along pressure gradients (INHALATION THERAPY, June 1957, page 13). Both O_2 and CO_2 are soluble in blood, but only sparingly; and because of this it is impossible for the blood to dissolve enough of either to carry the necessary quantities within the short time available. It has been calculated[1] that if the blood could carry only the amount of oxygen that it can dissolve we would have to have about 75 times as much blood in order to do the job.

Suspended in and carried by the fluid plasma are the formed elements of the blood — the red cells (sometimes called red corpuscles), the white cells (several kinds) and the platelets. The red cells are very intimately concerned with transport of the respiratory gases because they contain the substance hemoglobin, which is the actual carrier of most of the oxygen.

Gases diffuse through the walls of the red cells according to pressure gradients in exactly the same way they cross the membranes separating the air in the alveoli from the blood plasma in the pulmonary capillaries.

Blood plasma can carry small amounts of gases in physical solution (i.e., merely dissolved), and these gases exert tensions (tendency to leave the fluid) which correspond to the partial pressures of



TENSION OF O_2	152	152	152	152
VOLUMES OF O_2	0.2	20.0	20.0	10.0

Fig. 1. The tension of gas (e.g., oxygen) in any liquid is equal to the partial pressure of that gas in the gas mixture (e.g., air) with which the liquid is in equilibrium. At equilibrium the rate of entrance of oxygen molecules into the liquid equals the rate of exit of oxygen molecules from the liquid. From Carlson & Johnson.

the same gases in the medium with which the blood is in equilibrium—the air in the alveoli, for example.

To clarify this concept, consider the following example taken from Carlson & Johnson[2]: (See fig. 1.)

"Suppose we place in a large airtight container filled with air an open beaker of plasma, one of whole blood, one of hemoglobin in suspension in water (15 gm. per 100 cc.), and another of a more dilute suspension of hemoglobin in water, 7.5 gm. per 100 cc. Eventually, all the liquids will come into equilibrium with the air. Since the partial pressure of the oxygen of the air is 152 mm. Hg., and since equilibrium has been reached, then, by definition, the tension of oxygen in each of the liquids is also 152 mm. Hg. Yet, at this equilibrium point, the actual concentration of oxygen is quite different in the different liquids."

The plasma contains only 0.2 cc oxygen, the whole blood and the 15 gram hemoglobin solutions have 20, and the half-strength hemoglobin only 10 cc oxygen per 100 cc.

In practice, "tension" is very commonly referred to as partial pressure, since they correspond to each other and are expressed in the same terms, i.e., mm Hg.

Concentration vs Partial Pressure

The unwary may be easily confused by references to *concentration* of a gas and the partial pressure or tension it exerts. As is evident from the figure just referred to, the concentration means the actual amount present (free or combined), and is expressed as volumes per cent (vols %) – i.e., volumes per hundred volumes of the media it's in – usually this is the number of cc of the gas per 100 cc of blood, water, saline or whatever.

The partial pressure or tension of this same quantity of gas, on the other hand, can be quite a different matter. The reason for this is that gases which are combined with other chemicals into compounds

can no longer exert any pressure, since they are no longer merely in solution. So in the case of the hemoglobin inside the red cells, oxygen combines chemically with it to form oxyhemoglobin, and this takes the oxygen out of solution. As soon as that happens, the pO_2 of the inside of the cell falls, re-establishing the pressure gradient between there and the plasma. More O_2 automatically diffuses into the cell along the gradient, and this continues until the oxygen-carrying capacity of the hemoglobin has been reached. Then, since no more O_2 is being taken out of solution to form oxyhemoglobin, the pO_2 inside the cell rises until it is in equilibrium with that of the plasma outside the cell.

When this state has been reached (i.e., Hemoglobin 100% saturated with O_2), the partial pressures of oxygen of the plasma and of the hemoglobin solution inside the red cell are the same, but the oxygen concentrations are quite different. This is because the plasma can only carry what it can dissolve, but the hemoglobin solution not only dissolves O_2 but then takes most of it out of solution by combining it with the hemoglobin molecule.

Combination of Oxygen with Hemoglobin

Hemoglobin is a very large molecule composed of two main parts, heme and globin. The globin portion is itself a large protein structure with diverse possibilities for combination with other substances. The heme portion of each molecule of hemoglobin contains four atoms of iron, each of which can combine with one oxygen molecule.

The chemical union of oxygen with hemoglobin may be represented by the equation;

$$\text{Oxygen} + \text{Hemoglobin} \rightleftarrows \text{Oxyhemoglobin}$$

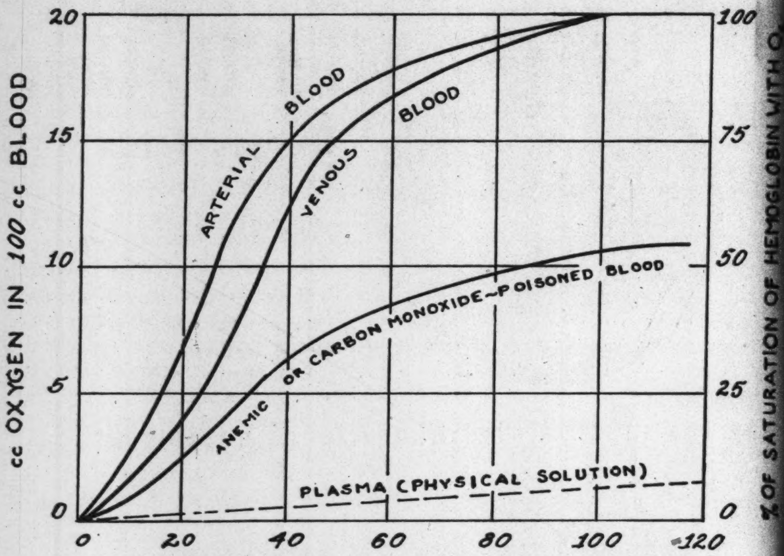
Since we will have to refer to these compounds often, it is customary to save space by substituting symbols for them, thus:

$$HbO_2 \rightleftarrows O_2 + Hb$$

It will be noticed that arrows are going in both directions between the two sides of the equation. This is because **this chemical reaction is capable of proceeding in either direction,** depending on the surrounding conditions. The most important factors affecting it are the pO_2, the pCO_2 and the acidity or alkalinity, but most especially the pO_2.

The Oxygen dissociation curves depicted in fig. 2 show us much about these effects. If samples of venous and arterial bloods and plasma are allowed to stand in closed chambers until they have come to equilibrium with partial pressures of O_2 of 20, 40, 60 etc. mm Hg, and then the samples are chemically analyzed for oxygen concentration (in vols %), the results can be plotted on a graph. The points thus determined are then connected by a smooth curve, and from the curve can be estimated other points which were not specifically determined.

For example, we see from the curve for arterial blood that at a pO_2 of 20 mm Hg the amount of O_2 the blood can hold is just over 6 vols %, and at 40 mm it is 15 cc per 100 cc. Those were both plotted points. From the portion of the curve connecting them, however, we can estimate that the O_2 con-



OXYGEN DISSOCIATION CURVES

Fig. 2. See text.

centration at 30 mm partial pressure would be about 12 vols %.

On the right side of the graph, for convenient comparison with the oxygen concentration values, are shown the degree of saturation of the hemoglobin with O_2 at each concentration. Note that this set of values uses the same horizontal lines on the graph, but assigns a different numerical scale to them. Only in this way can the one graph show just how nearly saturated the hemoglobin is with oxygen at any given O_2 concentration. It is seen that when the hemoglobin is 100% saturated (i.e., has taken up all the O_2 it can carry) the blood oxygen concentration is just 20 cc O_2 per 100 cc blood.

The graph here shows several different curves because arterial, venous and anemic bloods do not have the same O_2-carrying capacities. For comparison the capacity of plasma is also indicated. Venous blood carries less O_2 than arterial largely because it is more acid because of carbonic acid formed by the dissolved CO_2 it carries, but also partly because of a direct effect of higher pCO_2 itself.

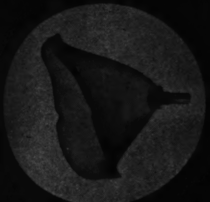
In typical anemic blood we have only about, for example, half as much hemoglobin. Where part, say half, of the hemoglobin is combined with Carbon Monoxide, there is not as much available to transport oxygen. Hence the curve for these conditions shows that oxygen-carrying capacity is reduced.

The curves on the graph show

Masks for medium concentration

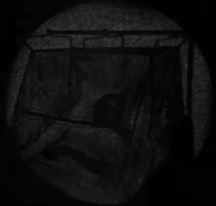
Masks for high concentration

Plastic Nasal Cannulae



Anatomical Face Cones

Plastic Oxygen Tubing



Oxygen Tent Canopies

Hudson Safety Humidifiers

Hudson Safety Jars Pint Mason

Hudson Infant Tents

the O_2-carrying capacities of the various kinds of blood at different oxygen tensions, but for practical purposes we are interested most in two points—the values at pO_2 of 40 and 100 mm Hg. These are the tensions we normally find in venous and arterial bloods in the human.

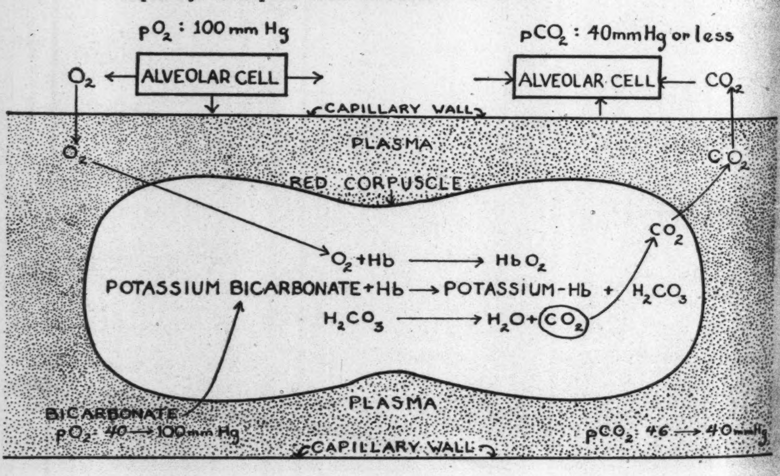
It can be seen that the oxygen concentration of the blood at these two partial pressures differs by 6 or 7 cc of oxygen per 100 cc of blood —i.e., each 100 cc of blood gives up 6 or 7 cc of oxygen to the tissues in its journey from lungs through the body back to lungs again. That would be 60 cc of oxygen supplied by a liter of blood. At rest our oxygen requirements run a little over 250 cc per minute, which, if 1 liter of blood can supply only 60 cc, means that the tissues need to be supplied with a little over 4 liters of freshly oxygenated blood each minute. The normal heart rate of the average adult at rest ranges between 70 and 80, and his heart pumps about 60 cc per beat; 75 x 60 = 4500 cc or 4.5 liters. In other words, we do supply as much as the calculated demand.

Another interesting fact to mention here is that the total blood volume of the average adult runs between 4 and 6 liters. This would mean, then, that in effect we circulate our entire blood volume through our heart and lungs once each minute—**at rest!**

Carbon Dioxide Transport

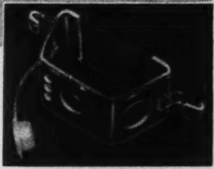
Carbon dioxide, even though it is a larger molecule than O_2, has certain chemical peculiarities which enable it to diffuse through cell walls more quickly and at lower pressure gradients than necessary for oxygen. Once in the plasma and dissolved, it promptly diffuses through the red cell wall into the interior fluid. Here, by means of a special chemical called an **enzyme** it reacts with water to form carbonic acid. The latter in turn enters into a reaction with the potassium salt of the protein part

Fig. 3 (a). Summary of physical & chemical events in blood of a pulmonary capillary. Compare with discussion in text.



These new NCG masks, used with an NCG nebulizer and large bore corrugated tubing, assure the soft, rolling supply of moist oxygen that is so necessary when nasal passages are by-passed. They completely cover the opening into trachea or larynx, to allow a high concentration of oxygen and humidity to be administered.

Made of clear lucite that is not irritating or toxic to the neck, the masks have a separate opening for applying suction without removal of mask, and emergency openings allow outside air if the oxygen supply is cut off. The straps on the tracheotomy mask are readily adjustable. All masks can be cold sterilized.



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of Hemoglobin, which results in the formation of potassium bicarbonate and a different (more acid) form of the hemoglobin molecule. In this solution the potassium bicarbonate molecule comes apart very readily, and the bicarbonate portion diffuses out of the red cell into the plasma. Most of our CO_2 is carried in this way—as bicarbonate in the plasma.

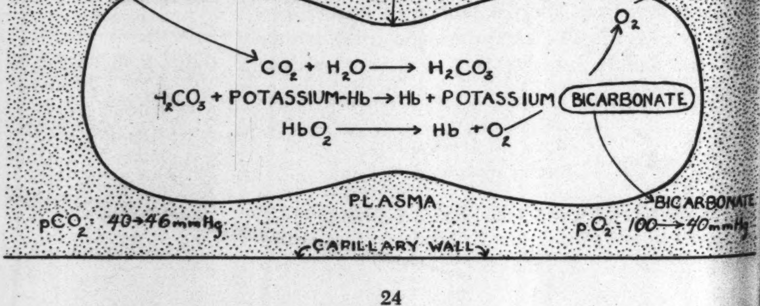
Some CO_2 combines directly with the protein portion of the hemoglobin molecule and is carried inside the red cell as carboxyhemoglobin. These reactions, like the ones with oxygen are reversible, and the direction they take depends on the conditions at the time. They are most affected by pCO_2, but also by pO_2 and alkalinity or acidity of the surroundings.

Summary

Figures 3a and 3b are very much simplified schematic drawings which help to summarize the physical and chemical phenomena responsible for transport of respiratory gases. They are in reality the same drawing, but one (a) shows the events going on between alveolar air and blood in the lungs, where O_2 is taken on and CO_2 given up, and the other (b) shows the same chain of processes reversed when the blood reaches the tissues and CO_2 is taken on and O_2 given up.

Look now at 3a. The scene is a capillary surrounding an alveolus. Oxygen proceeds from cells of the alveolus into blood because of difference in partial pressures. There the hemoglobin is only 60 or 65% saturated, so it quickly takes up O_2 to saturate itself. At the same time, CO_2 from the breakdown of carbonic acid (H_2CO_3) diffuses out into the alveoli because of gradient in that direction. As it leaves the blood, more bicarbonate shifts to carbonic acid, which then breaks down liberating more CO_2. The presence of high pO_2 causes the carboxyhemoglobin to give up its

Fig. 3 (b). Summary of physical & chemical events in blood of a capillary supplying an outlying tissue. See text for discussion.



CO_2 (in favor of O_2, for which Hemoglobin has greater affinity). This last reaction is not in fig. 3.

The combination of these processes results in a change in the pO_2 of the blood from about 40 to 100 mm Hg, and a change in pCO_2 from 46 to 40.

In 3b the scene shifts to a capillary of an outlying muscle. Here we see the reversal of the same reactions. The pressure gradients are just the opposite from those in the lungs, so O_2 diffuses outward and CO_2 into the blood. The chemical reactions are pushed in the other direction, so that more HbO_2 breaks down to Hb and liberates O_2. The Hb then can take up some of the CO_2, but most of the latter, as we have already remarked, is converted via carbonic acid to bicarbonate.

RECAPITULATION OF THE SERIES

In the first article, it was shown how the machinery of the thorax brings about changes in the pressure relationships between the inside of the chest and the outside air, resulting in movement of air in and out of the lungs.

The second considered various fractions of the lung volume and developed the concepts of partial pressures and diffusion along pressure gradients, and discussed ventilation and perfusion of the lungs, by which means the amount of oxygen getting into the blood is regulated.

The third dealt with the control of the foregoing processes by nervous and chemical mechanisms, and emphasized the fact that the whole process of respiration is geared more directly to the elimination of CO_2 than to the procurement of O_2, which is an incidental though of course necessary accomplishment.

This fourth part of the series has attempted to simplify the rather complex and interdependent physical and chemical events taking place in the blood as it passes through the capillaries of the lung and the body tissues, whereby it conveys O_2 from the lungs to the body tissue and CO_2 from the tissues to the lungs.

References:

1. Fulton: **Textbook of Physiology**, pp 806-12, 16th ed (1949) Saunders, Philadelphia
2. Carlson & Johnson: **Machinery of the Body**, pp 254-5, 4th ed (1953) University of Chicago Press.

Acknowledgment:

Figure 1 is reproduced without change from Carlson & Johnson, with permission of the publisher.

Figures 2 and 3 are redrawn and simplified from Fulton. Once more we wish to thank Mrs. Rosemary Whitacre for the painstaking job of producing the drawings for these illustrations.

Inhalation Therapists

continued from page 14

Boyd, Head, Inhalation Therapy Department, Jackson Memorial Hospital, Miami, Florida; and James F. Whitacre, Chief Inhalation Therapist, Strong Memorial Hospital, Rochester, New York.

Other Directors of the American Association of Inhalation Therapists are: Noble Price, Chief Inhalation Therapist, Methodist Hospital, Indianapolis, Indiana (1958); Sister M. Yvonne, Director of Anesthesia, St. Francis Hospital, La-Crosse, Wisconsin (1958); and James Sharkey, Senior Inhalation Therapist, Queen Mary's Veterans' Hospital, Montreal, Quebec, (1959).

ABSTRACTS

"Nitrogen Dioxide Pneumonia," by R. R. Grayson, M.D., in *GP*, November 1957, p. 90.

Dr. Grayson points out that the pulmonary disorders which have been known variously as "silo-filler's disease," "farmer's lung," "thresher's lung," etc., have been found to be due to inhalation of Nitrogen Dioxide (NO_2), which is present in fermenting ensilage.

He also shows that this gas is commonly found in the smoke of fires where nitrate compounds (plastics) are burning, and is a constituent of the smogs over large industrial cities.

Nitrogen Dioxide has a pungent and sweetish but offensive odor which is detectable in concentrations as low as five parts per million. It is a reddish gas when pure, but is not visible in air until concentration reaches 75 to 150 ppm. Inhalation of the gas produces no immediate irritation, but after a latent period ranging from several hours to several days, severe pulmonary symptoms develop. These include bronchitis, bronchopneumonia, acute pulmonary edema and broncholitis fibrosa obliterans (an inflammation of bronchioles accompanied by obliteration of some of their lumens by fibrous connective tissue) – individually or in combination.

Dr. Grayson thinks the reason for the delay in onset of the symptoms is time required for the gas to penetrate through mucus lining the lungs. It reacts with water there to form nitrous and nitric acids and other substances. He feels that the inhalation of alkaline aerosols, like sodium bicarbonate (as in Alevaire) is of definite benefit in preventing the symptoms appearing, if this is done early after exposure and before their onset.

Treatment once the syndrome has appeared is mainly supportive, and consists of oxygen with detergent aerosols and bronchodilators as needed, antibiotics to combat secondary infection, and digitalis and steroids where indicated.

"Respiratory Function in Emphysema in Relation to Prognosis," Bates, Knott and Christie, *Q J. Med* 25:137 (1956).

These investigators followed a group of 59 patients over a period of 5 years. During this time, estimates of vital capacity, maximum breathing capacity, functional residual capacity, mixing efficiency and diffusing capacity (a measure of the quantity of a gas, such as O_2, which can pass from the alveoli into the blood per minute with a pressure gradient of 1 mm Hg.) were made.

Although all these tests are of value in diagnosing emphysema, there is poor correlation of their results with the true course of the patient's illness, with the exception of the diffusing capacity, which is a relatively sensitive guide to the prognosis.

"There are two distinct processes in emphysema which usually run concurrently, but which may be independent of one another. The first is bronchial obstruction, and this is mainly responsible for the dominant symptom of this disease, which is dyspnea. The other, which may be responsible for no symptoms until it leads to heart "failure, is the reduction of the pulmonary capillary bed. The latter process, which is most closely related to prognosis, can only be satisfactorily

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assessed by measurement of the pulmonary diffusing capacity."

They explain how diffusing capacity is influenced by changes in the lung tissue itself, and by varying degrees of bronchospasm. The bronchospasm can be relieved to some extent by bronchodilators, but the progressive changes in the lung tissue itself are irreversible, and it is these changes which in the end put such a burden on the circulation of the right heart that it fails. (cor pulmonale).

"Diving Medicine" by Lt. Edward Lanphier, M.C., U.S.N., in *New Engl J. Med* 256:120 (1957)

"One of the most important recent developments in diving medicine is its growing significance for the medical profession as a whole. New types of diving equipment and new technics have not only broadened the scope of diving to include important new military, scientific and commercial applications, but also opened it to the average man as a fascinating and practical sport. A phenomenal increase in the number of persons involved in diving has resulted. As a consequence, medical problems that once could be left to the Navy's handful of submarine diving medical officers now confront civilian practitioners in many parts of the country." Thus Lt. Lanphier opens his comprehensive article on this important subject. It is clear that inhalation therapists in these parts of the country will also be coming into contact with patients who have gotten into diving accidents.

Lt. Lanphier is not talking about persons who put on flippers and a face mask, and whose underwater excursions are limited by their ability to hold their breath. He is concerned with those who buy SCUBA (self-contained underwater breathing apparatus), and are able to submerge to depths and for time intervals formerly only possible for professional divers.

The lack of a lifeline and air hose connection to the surface, though it does permit greater freedom, has *not* lessened the number or degree of dangers the diver is exposed to. On the other hand, equipped with the necessary knowledge of the physiology of underwater diving and safety precautions he should respect, the diver is in probably no greater danger than any other sportsman.

Technical Tips

Croupette Users! Croupettes as supplied by the manufacturer have pint bottles for distilled water for the nebulizer. We have found that these do not require refilling so often if they are removed and quart jars substituted. This of course necessitates replacing the plastic tube that carries water up to the nebulizer with a longer piece of tubing.

There is one drawback to this, and that is that the Croupette then cannot rest on its feet, but rests on the bottom of the jar. This is of no consequence while it is on the patient's bed, but when standing the tent up in other locations, care must be exercised to balance it or lean it against something to prevent falling. The quart bottle extends only about an inch below the Croupette legs, and we think the manufacturer ought to make them stand that much taller to accommodate the quart bottles!

Tent Flowmeter Damage in Transit. It is not a new practice to store regulators on mounting studs on boards to keep them from rattling around on shelves, and recently oxygen tents have been coming onto the market with such studs for mounting the regulator to keep it safe while moving the tent from storage to patient or back.

One eastern hospital was confronted, however, by the problem of a lot of old tents without this feature, and also by the fact that piped oxygen was in use and flowmeters instead of regulators were therefore carried with the tents. These were laid on top of the tents, along with tubing and electric cord, and frequently in the course of passing over elevator sills, etc., vibration would shake them off and break them on the floor.

This was avoided by mounting studs on the tops of the tents threaded exactly like pipeline outlets—onto which the flowmeters could be securely screwed to keep them safe in transit. This also gave a post around which to wind the electric cord and tubing to keep them off the floor and out from under wheels.